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Domestic Burning of Fuelwood in a Subsistence Tribal Economy of Lower Himalayas, India: Some Implications Based on Exploratory Analysis

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Abstract Fuelwood is important source of cooking energy in the majority of households of rural India. This paper discusses positive and negative externalities of fuelwood use including forest conservation and the health, welfare and environment for the forest-dependent tribal community of Jaunsar, based on survey data and visual observations from this remote area of the Lower Himalayas, India. Health issues due to fuelwood use are explored among tribal women using data collected from 50 randomly selected households spread in 13 randomly selected villages. The pattern of fuelwood use including hardships in terms of time spent and distance travelled for collection of cooking energy and the kitchen structures are also elaborated. The emission of four major pollution gases—CO, SO_x, NO_x and CO_2—due to fuelwood burning in kitchens is found to be beyond acceptable air standards, causing various reported health problems. Policy implications arise concerning options of local people to utilize other energy options. It is argued that the adverse impacts should be tackled by framing household energy policy in totality, not limited to concern over the energy crisis but also considering associated implications including health and drudgery.

Keywords Forest dependent community · Health hazards · Pollution · Domestic energy · Alternate energy

Introduction

Biomass burning includes burning of living and dead vegetation, including fuelwood use and forest fire. About 90% of all biomass burning is due to human

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induced activities, including agricultural expansion, bush control, weed and residue burning, and harvesting forest products. It is estimated that 8.7 billion tonnes of dry biomass per year are burnt in the world (Koppmann et al. 2005).

Solid fuels are used for burning to fulfill various energy needs of about half the world's population; this includes 20% in Europe, 80% in Central Asia and more than 80% in sub-Saharan Africa and South Asia (Bruce et al. 2000; Holdren and Smith 2000; Smith et al. 2004; Rehfuess et al. 2006). These fuels produce high levels of pollutants due to inefficient and incomplete burning in traditional stoves (Ezzati and Kammen 2002). Indoor air pollution, generated due to incomplete fuelwood burning, is the clearest and most direct physical health risk, and there is now consistent evidence that biomass smoke exposure increases the risk of a range of common and serious diseases of both adults and children (Bruce et al. 2000). Family members present either in kitchens or close to them are being exposed to the highest pollutant levels because most of the chullas (cooking stoves) used do not have flues or hoods to take the pollutants out of the living area (Smith 2002; Bennett et al. 2002). Moreover, if vented to the outdoors, the fuelwood produces enough pollution to affect the local neighbourhood, with implications for exposures (Smith and Liu 1994).

Exposure due to use of solid fuel increases the risk of diseases including pneumonia, chronic respiratory disease and lung cancer, and is estimated to account for a substantial proportion of the global burden of disease and ill health in developing countries (von Schirnding et al. 2002). Other important short-term health impacts include burns to children, and neck, back and head injury to women from carrying fuelwood loads (Pandey 1997). Furthermore, a range of interrelated quality of life, economic and environmental consequences of household energy use affect human health, with loss of educational and income generating opportunity (Bruce 2002; Laxmi et al. 2003).

In India, nearly 700 M people do not have access to clean energy, and depend on traditional and unprocessed fuels (Registrar General of India 2001a). The energy use pattern in rural India is changing, with uptake of clean energy, but traditional fuels including fuelwood, crop residue and cow dung still constitute the main source of household cooking energy due to inadequate and unreliable supply of clean energy (Balakrishnan et al. 2004) particularly liquid petroleum gas (LPG), with penetration limited to economically affluent rural households (Nautiyal and Kaechele 2008). Moreover, the effort and time spent in collecting biofuels have been increasing throughout the developing world (NSSO 1997; Singh et al. 2010), because of localized deforestation due to anthropogenic causes (Osei 1993).

Biomass accounts about 84% of the total energy use in rural Indian households, with fuelwood being the dominant form (Patil 2010). The high reliance on fuelwood among the biomass fuels is due to its high thermal efficiency that substantially reduces cooking time, and lack of alternative biofuels (World Bank 2004). Fuelwood for cooking energy is collected from forests without cash expenditure by women in Indian community, and they are therefore exposed to many kinds of stresses and hazards. The use of fuelwood energy causes physical deformity, due to the need to carry heavy loads, increased cleaning burden (for kitchen utensils, walls, floors and clothes), as well as causing ecological damage (Laxmi et al. 2003). The

manifestations of this stressful existence include: (1) physical injuries (e.g. falling from trees and steep slopes, snake bites and attacks from wild animals), (2) the drudgery of hard labour, often for 12–14 h a day, (3) much reduced time for childcare, and (4) stress and increased vulnerability to diseases (Mishra 2004).

The collection and utilization of fuelwood from forests is a matter of great concern to policy planners, in relation to forest conservation and to adverse impacts on human health. The burden of disease due to indoor air pollution is highly concentrated among society's most vulnerable groups (women and children in poor rural households) due to their high exposure to smoke, and ultimately reduces the availability of quality of the labour force in economic terms. Therefore, fuelwood use and associated problems coupled with expanding access of clean fuel have to be addressed in a more effective way by reducing dependency on biomass cooking energy (Sharma et al. 2006). These efforts will facilitate attainment of the defined Millennium Development Goals (MDGs) of India.

This paper examines the issues pertaining to use of fuelwood from a policy perspective in relation to a case study in the mountainous region of lower Himalayas in India. The objective is to clarify the existing scenario of fuelwood use through collecting relevant data from households including the measurements of emitted pollutants. The analysis is focused on the impact of fuelwood use for the long-term sustainability of households, environment and forests in the long terms from a development perspective. The regional assessment of fuelwood exposure would guide the pathways for the developing strategies for achievements of the MDGs.

The Study Area and Research Method

The study area, a tribal region known as Jaunsar Bawar, is located in Dehradun districts of Uttarakhand state, in the North and Northeastern zone of the Indian Peninsula. It lies between latitudes 30°-31′ and 31°-3′-30′N and longitudes 77°-45′ and 78°-7′-20′E. The total geographic area is 1,002 km^2 and 64% is forest land. The altitude ranges from 405 to 3,071 m with temperate climate at higher elevations and high temperatures in lower river valleys of the Tonns and Yamuna Rivers. The average annual rainfall is about 175 cm. The forest cover in the region consists of conifers on the higher elevations and broadleaf forests at lower altitudes. The households are primarily dependent on the forests for their livelihoods. The major forest tree species used as fuelwood in the region include ban (*Quercus leucotrichophora*), ayar (*Pieris ovalifolia*), thanboi (*Cornus capitata)*, burans (*Rhododendron arboreum*), kharik (*Celtis australis*), moru (*Quercus dilatata,* Lindl.), chulu (*Prunus armeniaca*), kharshu (*Quercus semecarpifolia,* Smaith), and the main shrub species used as fuelwood are kashmoi (*Berberis lycium,* Royle) and bhekoi (*Prinsepia utilis,* Royle) (Pandey 2007).

To examine health problems caused by the use of fuelwood in livelihood systems, primary data were collected from 50 randomly selected households spread over 13 villages during March to April, 2008. Six clusters of adjoining villages (13 villages in total) were first selected, keeping in view the homogeneity among adjoining villages. From these clusters, 7 to 10 households, constituting a total of 50

households (respondents) were selected at random proportional to the total number of households in the cluster, which ranged from 33 to 48. A questionnaire was developed to seek information on socio-economic attributes, forest utilization and associated health hazards. The questionnaire was tested on 15 households, and some modifications made; some questions leading to quantification of fuelwood and health parameters were deleted because of similarity of responses, fuelwood quantity was defined in terms of bundles (1 bundle equals to approximately 20 kg), and more health indicators dealing with eye-related issues were added as well as household distance from doctors and hospitals. Household interviews were then conducted, by a local resident in their local dialect, under the supervision of the researcher.

Physical Indoor Air Quality (IAQ) measurement was carried out for a sub-sample of 20 of the selected households. IAQ was assessed by measuring concentrations of emitted gases from fuelwood burning in traditional stoves after 1 h since start of burning by placing calibrated portable sensoring instruments approximately 1.5 m above the mouth of burning stoves. A 'Multi-gas Analyzer' for SO_2 and NO_2, a 'CO Analyzer' for carbon monoxide and a 'Gas Alert Micro 5-IR' for CO_2 measurement were used. The measurements are considered as the indices of exposure during cooking to hazardous gases by the cooks, primarily middle-aged women, due to dispersal in the nearby atmosphere. The estimation of suspended particulate matter (SPM) emission was carried out with the help of a Whattmann filter paper of 9.5×13 inches placed on the house rooves above the mouth of stoves for 1 h from the commencement of combustion in chulhas. The filter paper was desiccated and weighed in a laboratory, and the difference in weight after and before exposure was taken as the weight of SPM during the period of combustion.

Observations and Results

The descriptive statistics of household attributes which directly or indirectly govern the quality of life of the people of Jaunsar, together with health and fuelwood dependency parameters, are summarized in Table 1. Jaunsary families were in general found to be extended families, with a maximum of 29 members and an average of 14 members. The primary source of income for 95% local people was agriculture. Monthly income of respondent households varied from Rs 1,500 to Rs 13,000 ($ US 33–287) while average monthly expenditure was Rs 3,200 ($71), which is lower than the poverty line (Rs 486/person) of Uttrakhand state as defined by the Planning Commission of India (2009). Most of houses were found to be constructed of kachha (mud and thatch) (76%), the remainder being semi-pucca (mud, thatch and brick 8%) and pucca (brick and cement 16%). Landholding size varied from 0 to 3 ha with an average of 0.5 ha but with almost 80% of the landholdings being 0.8 ha or smaller. The area of irrigated land averaged only 0.02 ha per household, mainly due to lack of irrigation facility and hilly terrain. About 14% of households were engaged in labouring work, 6% were artisans and 14% were salaried employees (particularly labour engaged through contractors as a secondary income source).

Table 1 Demographics and cooking energy parameters of sample households

Parameter	Mean ± SE	Minimum	Maximum
Family size (persons)	14.16 ± 1.82	5	29
Total land area (ha)	0.51 ± 0.08	0	3.25
Irrigated land area (ha)	0.02 ± 0.01	0	0.41
Income per household per month (Rs)	3,951 ± 343.1	1,500	13,000
Expenditure per household per month (Rs)	3,200 ± 289.1	1,200	12,500
Distance of household from road (km)	2.07 ± 0.19	0	5
Distance of household from forest (km)	2.04 ± 0.25	0.10	5
Amount of fuelwood collected per day (bundles)	1.72 ± 0.11	1	4.50
Distance traveled for fuelwood collection (km)	2.10 ± 0.19	1	4
Time spent for fuelwood collection (h)	3.35 ± 0.23	1	7

Collection of Fuelwood for Cooking Energy

People of Jaunsar were highly dependent on forests, all using fuelwood, primarily for cooking and heating. However, 10% had liquefied petroleum gas (LPG) stoves and 2% kerosene stoves, for occasional use. High dependency on fuelwood was associated with free access to forests, poverty, irregularity of employment in crop cultivation, and unavailability or unaffordability of other fuel. Nineteen of the 50 respondents wished to shift to alternatives fuel sources with subsidy support. However, the 12% of respondents who are well off also used fuelwood because it is a free commodity. The fuelwood was mainly obtained from government forests; only 4% collected fuelwood from their own land. Fuelwood collection was found to be a joint effort of both individual households and the community, and mostly dominated by females.

Although the Jaunsar area, a hilly region, supports highly to moderately dense forests, some residents have to travel long distances for fuelwood collection. The distance from the village of the forest was typically 2–3 km. The local people typically spent daily 3–4 h, and up to seven hours including travel time for collecting fuelwood. The amount of fuelwood collected mostly ranged from 1 to 4 bundles (each about 20 kg) every second day. Usage was high in winter for room heating. The amount of fuelwood used per household for cooking varied according to the family size with an average of 1.72 bundles per day. The annual average household fuelwood extraction from forests was approximately 0.17 M tonnes for the total 14,399 households of Jaunsar region (as per Registrar General of India 2001b).

Kitchen and Cooking Process Adopted

Cooking is traditionally women's work in the Jausary community. The kitchens are mostly located indoors with only 6% of households (mostly those with insufficient space for kitchen in their house) having outdoor kitchens. The kitchens mostly have

a single door, which is also used as entry to the house. Smoke is released through a hole on the roof above the chulha and by a small window on the side wall in most kitchens. Only 4% had an outside chimney to vent smoke. The traditional cooking equipment (the chulha) is U-shaped with three-openings above one fire and is made of locally available raw materials of mud mixed straw or dry grasses and stones. Usually the wife of the head of the household (60%) or the daughter-in-law (40%) did the cooking. In some households, more than one person was involved in cooking activity. Nearly 3 h was spent in cooking per meal in the morning and again in the evening. Concentrated smoke was emitted initially from chulhas for typically only 10–20 min per meal.

Measurement of Air Pollution in Kitchens Due to Fuelwood Burning

Concentrations of various gases being emitted due to incomplete combustion of fuelwood in kitchens after 1 h burning, measured for 20 kitchens through the portable devices, are reported in Table 2. It was observed that after 1 h of chullha burning, the mean SO_2 and NO_2 concentration were 2.55 and 1.73 ppm, respectively. The level of both gases was much higher than the national mean maximum acceptable level set by Central Pollution Control Board of India. However, the most critical in terms of health impact was CO, which reached a mean concentration as high as 57.7 ppm in Jaunsary kitchens after 1 h of chullha burning. The major gas responsible for climate change (CO_2) was found in concentrations of up to 2,850 ppm in kitchens with a mean of 1,179 ppm, which was also much above than the general concentration of CO_2 in the atmosphere. The contribution of suspended particulate matter was also high, with a mean of 0.38 g (Table 2). Clearly, these communities, especially women and children, have routine exposure of high concentration of pollutants (particle and gases) during meal preparations and thus vulnerable to health hazards.

The correlation coefficient between the quantity of fuelwood burnt and volume of gas release after 1 h was non-significant for CO_2, CO and NO_2 but significant for SO_2 concentration. The lack of significance may also be attributed to low variation in quantities consumed and small size of samples.

Table 2 Estimates of GHGs and SPM due to fuelwood combustion (n = 20)

Pollutants	Minimum	Maximum	Mean	Std error	Standard limit[a]
SPM (gm)	0.10	0.90	0.38	0.20	0.14
NO_2 (ppm)	0.20	2.70	1.73	0.18	0.04
CO (ppm)	1.80	129.60	57.69	11.48	40.00
SO_2 (ppm)	0.1	5.00	2.55	1.16	0.03
CO_2 (ppm)	150	2,850	1,178.57	261.34	–[b]

All measurements were made inside kitchens after 60 min of chulha burning

[a] *Source* CPCB (2007)

[b] No upper limit is prescribed, therefore compared with general concentration in atmosphere

Health Hazards due to Fuelwood Use

During the survey the basic problems faced by the households and associated reasons for the problems were explored. Females involved in cooking were grouped into age classes of 18–35 and over 35 years. The major problem faced by the 18–35 age group were eye-related while those above 35 had a number of problems with headache and back pain being notable based on reported symptoms (Table 3). Eye-related problems of the over 35 age group were comparatively low because they were usually not associated with cooking at similar intensity to those of the 18–35 year group. Only low incidences of respiratory problems were reported because mostly people ignored these and considered them part of their routine hard life (Table 3). Most were unable to identify their respiratory problems and unable to discriminate the causes.

The major reasons for the above problems were the use of fuelwood in case of the age group 18–35 females while females aged over 35 years identified fuelwood burning and collection and both, as well as age and work pressure. However, fuelwood burning was the major cause for eye-related problems.

Medical expenses averaged Rs. 64 per month per household with less than one visit, on average, to a doctor in a month (Table 4). The lack of adequate road and hospital facilities affects the frequency of visit to doctors. Due to the shortage of trained doctors, the average distance of households from a hospital was more than 9 km and the maximum distance to an untrained doctor (with no professional medical training but experience acquired working with trained doctors) was about 2 km. Due to poor infrastructure including roads and the distance from households to nearest motorable road (averaging about 2 km), it was difficult for villagers to visit a hospital even when they required medical treatment. Members of most

Table 3 Proportion of females reporting health hazards due to fuelwood use by age class (%)

Problem	Symptoms	Age group	
		18–35	> 35
Respiratory system	Coughs and colds	28	22
	Attack of wheezing	0	4
	Breathing problem	14	18
	Breathing problem while walking	0	0
	Bringing up phlegm	2	2
	Chest problem	0	0
Cooking-related problem: eyes	Watering of eyes	44	26
	Visibility problem	40	24
	Eye redness	38	28
	Headache (regular)	33	22
Transportation problem	Headache	24	30
	Back pain	34	36
	Leg pain	36	22

Table 4 Parameters related to medical treatment

Parameter	Mean ± SE	Minimum	Maximum
Household distance from hospital (km)	9.44 ± 0.59	0.50	17.00
Household distance from trained doctor (km)	9.44 ± 0.59	0.50	17.00
Household distance from untrained doctor (km)	0.58 ± 0.13	0	2
Medical expenses per month per Household (Rs.)	64 ± 15.45	0	350
Household frequency of visit to doctor (number/month)	0.45 ± 0.13	0	3.00

households had not visited a doctor in the last 3 months. This situation reflects the low standard of living of the Jaunsary community. Lack of entitlement to medical treatment from the state and poor health reduces the productivity of the females and hence overall family welfare, and is associated with subsistence living for generations. The reason for the poor health status may also be the unscientific construction of kitchens with minimal ventilation for smoke from fuelwood burning.

Synthesis of Fuelwood Use Implications

The proportion of the use of traditional stoves not under a chimney, place of cooking and use of fuelwood as cooking energy in the region is slightly higher than that derived in the third National Family Health Survey for the state of Uttrakhand (NFHS 2008). The rural household cooking energy consumption per household is similar to the national average for LPG and kerosene, but fuelwood consumption is much higher, with more than 85% share of household energy against the national average of 75% (reported in NSSO 2007). The volume of fuelwood use is much higher than in the Himalayan region (reported in Singh et al. 2010), which may be attributed to the ready availability of biomass due to high forest area in the region, together with low development, poor access to the clean energy and prevalence of poverty. As observed by Saghir (2005), high reliance on biomass energy has major implications for economic development, livelihoods, social dignity and environmental sustainability. Use of fuelwood leads to a vicious cycle of linked activities and the position of 'poor individual' and 'poor state' (Patil 2010).

Based on the study, it can be concluded that the situation for public health and environment in the mountainous rural region of Jaunsar is grave due to high usage of fuelwood. It can be concluded that a severe loss in quality of life is suffered due to fuelwood burning emissions, on top of that from fuelwood collection effort and cooking time relative to use of gas and electricity. This leads to a classification of the impacts of fuelwood use into categories of forest conservation, health, welfare, environment and climate change, as in Table 5.

Policy Implications

Rural people in Jaunsar region are unable to overcome the fuelwood associated problems for various reasons, including lack of infrastructure. However an indirect

Table 5 Summary of potential impacts and externalities of fuelwood use

Impact area	Possible positive impacts	Possible negative impacts	Externality (positive and negative)
Health			
Health effects (use as cooking energy in kitchen)	Removal of house flies and other small insects due to smoke during cooking process, which reduces the potential agents of infectious diseases	Various respiratory and eye-related health issues due to smoke emission from incomplete combustion.	No expenditure for removal of house flies, due to smoke. Some indirect expenditure for health remediation
Health effects (during collection and transportation)	Clean air for breathing	Bone fracture and injuries due to falling from tree and during fuelwood transportation. Ergonomic health outcome, which deformed bones due to load	Reduction in labour force due to fuel wood lead health effects, which indirectly affect either household income generation
Environment			
Local environment (household and local area)	Increase in house temperature, conducive to living in this cold region	Mixing of emitted polluted gases and SPM in the local environment	Indirect expenditure for remedial measure and more labour for cleaning of kitchen and utensils.
Climate change			
Carbon	High emission of carbon dioxide leading to complete combustion with high thermal efficiency	Loss of carbon, which has been stored in the vegetation through carbon sequestration	Potential serious future implication once carbon payment for conservation of natural forests is operational. Emission-lead impact on climate change
Tree cover			
Fuelwood as cooking energy	Removal of dead and fallen twigs and branches, which reduce chances of fire	Unsustainable pruning and cutting of trees, which leads reduction in tree cover	Loss in State revenue against the illegal removal and regeneration loss in forests
Labour			
Labour force utilization	Use of unproductive labour, which is abundantly available in the region due to large families	Poor and ineffective use of available manpower for collection and processing of the fuelwood	Reduced income earnings due to saving against the price of cooking energy, which could be much more
Income levels			
Poverty and income	Savings due to free availability of fuelwood for energy use	Reduced opportunity and impetus for adopting alternatives of fuelwood	Saving against expenditure on fuelwood purchase, Reduction in opportunity for alternative fuelwood

Table 5 continued

Impact area	Possible positive impacts	Possible negative impacts	Externality (positive and negative)
Accessibility and enjoyment			
Access to and enjoyment of forests	Pleasure due to scenic beauty or calm and serene environment during visit or forest collections	Reduced forest access for future generation. Loss of scenic beauty	Lack of entitlement to future generation due to reduction in opportunity

cause may be low education status and low employment opportunities. The means of solving these issues are location-specific because these issues depend not only on the quality and quantity of fuelwood and the kitchen design, but also household economic status. Hence strategies to reduce health hazard may be considered through changes in energy technology, use of surplus labour, and creating income earning opportunities (Mishra et al. 2002). The economic issue can be addressed by mobilizing surplus unproductive labour in income-generating activities. The locally available raw material including forest products may be utilized for local small-scale value-adding processing, generating additional income. Increasing household literacy especially for females would provide a more robust solution by increasing decision-making ability. Changes in the structure of housing such more ventilation or partitioning off kitchens from living areas can have a major impact on reducing pollution exposure. Selection of low-smoke tree species and drying of fuelwood before burning can reduce cooking emissions.

Establishment of a well-equipped and staffed medical centre is a state responsibility, but requires a huge financial investment. This may be addressed by organizing regular medical camps in remotely located villages staffed by trained doctors. Additionally, there is need for a public campaign to inform people about the associated loss and health risks of exposure to cooking smoke. In designing and implementing policies and intervention programs, such as the improved cooking stove program and kitchen structures with greater ventilation, special attention should be given to the local community needs and the needs of women, who are responsible for cooking.

Reduced use of fuelwood could be achieved by large-scale dissemination of LPG at subsidized rates. Replacing firewood with LPG or other alternatives to provide energy for cooking, either free of cost or at an affordable rate, will reduce kitchen emissions and their health impacts. Shifting away from fuelwood would increase the carbon stored in forests, thus supporting climate mitigation and enhanced ecosystem services. It would also reduce the drudgery in women's lives and harm to their health, and help to improve their quality of life, thus facilitating pathways to achieve the MDGs. Use of alternative energy sources will also have some negative environmental implications, though at reduced level. Assuming at the present market rate of approximately Rs 350 per cylinder refilling cost including transport, and use of two LPG cylinders per month (24 per year) by all 14,400 households of Jaunsar, the annual liability to the government would be Rs 12 M with full subsidy.

This large cost for a small number of households reveals that full subsidiziation of LPG to enable a switch to this fuel type would not be financially feasible in the foreseeable future.

The use of clean fuel and particularly LPG is limited to infrequent occasions by a small proportion of relatively well off households in the study region. The limited penetration may be attributed to the high gas cost for refilling, with high initial cost of equipment (stoves and cylinders), and poor supply of cylinders. These constraints inhibit the households to wider adoption, in spite of prevailing subsidized prices (Pachauri and Jiang 2008). The remoteness, low demand in villages due to low population density, poor road connectivity and low incomes in rural areas are challenges to commercial viability of the LPG distribution network at current prices (ESMAP 2003). Therefore, measures by the federal and state governments are needed to support the extension and dissemination of clean and efficient source of energy—including fossil fuel and biomass energy—in combination with infrastructure improvements for energy supply and greater income earning opportunities for rural people.

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